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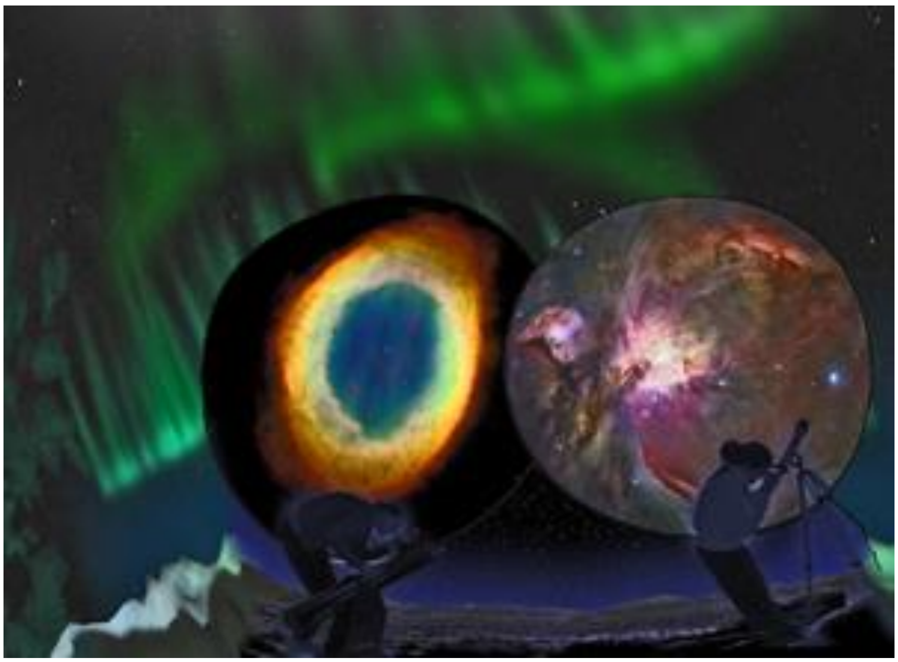

# Cosmic Colors

## An Adventure Along the Spectrum

Compiled & Edited by
Leisa Preble

THE UNIVERSITY OF MAINE

*A Member of the University of Maine System*

Emera Astronomy Center
and M. F. Jordan Planetarium

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## An Adventure Along the Spectrum

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**Mission Statement:**
The mission of the Maynard F. Jordan Planetarium of the University of Maine is to provide the University and the public with educational multi-media programs and observational activities in astronomy and related subjects.


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# Cosmic Classroom

Looking for fun and interesting space activities? The planetarium staff has prepared a collection of materials we call the Cosmic Classroom for you to use before and/or after your visit. These materials are entirely for use at your own discretion, and are not intended to be required curricula or a prerequisite to any planetarium visit. The Cosmic Classroom is one more way that the Jordan Planetarium extends its resources to help the front line teacher and support the teaching of astronomy and space science in Maine schools.

The lessons in this Cosmic Classroom have been edited and selected for the range of ages/grades that might attend a showing of this program at the Jordan Planetarium. Those activities that are not focused at your students may be adapted up or down in level. Our staff has invested the time to key these materials to the State of Maine Learning Results in order to save you time.

The State of Maine Learning Results performance indicators have been identified and listed for the program, the Cosmic Classroom as a package, and each individual activity within the package. The guide also includes related vocabulary and a list of other available resources including links to the virtual universe. We intend to support educators, so if there are additions or changes that you think would improve, PLEASE let us know.

Thank you, and may the stars light your way.

*The Maynard F. Jordan Planetarium Staff*

## The Program – Cosmic Colors: An Adventure Along the Spectrum

The nature of color affects all of our perception of the universe from telescope images to invisible light that cooks our popcorn. We experience light every day. But the light we see is only a small part of the vast energy scale that we call the electromagnetic spectrum. Explore the source and qualities of color in this Omnidome show that takes visitors from inside the eye to the farthest reaches of space. We're very glad that you have chosen to visit our planetarium with your group. We hope that this guide either will help you prepare your group or help you review their experience at the University of Maine's sky theater.

## State of Maine Learning Results Guiding Principles

The lessons in this guide, in combination with *Cosmic Colors: An Adventure Along the Spectrum*, help students to work towards some of the Guiding Principles set forth by the State of Maine Learning Results. By the simple act of visiting the planetarium, students of all ages open an avenue for self-directed lifelong learning. A field trip encourages students to think about learning from all environments including those beyond the schoolyard. A Jordan Planetarium visit also introduces visitors to the campus of the largest post-secondary school in Maine and encourages them to think of this as a place which holds opportunities for their future education, enjoyment and success.

Other sites on the University campus, including three museums, explore a variety of subjects, and the Visitors Center is always willing to arrange tours of the campus. A field trip can contribute to many different disciplines of the school curriculum and demonstrate that science is not separate from art, from mathematics, from history, etc. The world is not segregated into neat little boxes with labels such as social studies and science. A field trip is an opportunity for learning in an interdisciplinary setting, to bring it all together and to start the process of thinking. For a more complete discussion of field trips, please visit the Jordan Planetarium web site at http://www.GalaxyMaine.com.

If used in its entirety and accompanied by the Planetarium visit this guide will help students to:

Become **a clear and effective communicator** through

A. oral expression such as class discussions, and written presentations
B. listening to classmates while doing group work, cooperation, and record keeping.

Become **a self-directed and lifelong learner** by

A. introducing students to career and educational opportunities at the University of Maine and the Maynard F. Jordan Planetarium.
B. encouraging students to go further into the study of the subject at hand, and explore the question of "what if?"
C. giving students a chance to use a variety of resources for gathering information

Become **a creative and practical problem solver** by

A. asking students to observe phenomena and problems, and present solutions
B. urging students to ask extending questions and find answers to those questions
C. developing and applying problem solving techniques
D. encouraging alternative outcomes and solutions to presented problems

Become **a collaborative and quality worker** through

A. an understanding of the teamwork necessary to complete tasks
B. applying that understanding and working effectively in assigned groups
C. demonstrating a concern for the quality and accuracy needed to complete an activity

Become **an integrative and informed thinker** by

A. applying concepts learned in one subject area to solve problems and answer questions in another
B. participating in class discussion

# State of Maine Learning Results Performance Indicators

In conjunction with the Maynard F. Jordan Planetarium show *Touching the Edge of the Universe* this guide will help you meet the following State of Maine Learning Results Performance Indicators in your classroom.

## Grades 3-5

### Science and Technology –

B1.Skills and Traits of Scientific Inquiry

a. Pose investigable questions and seek answers from reliable sources of scientific information and from their own investigations.

b. Plan and safely conduct investigations including simple experiments that involve a *fair test*.

c. Use simple equipment, tools, and appropriate metric units of measurement to gather data and extend the senses.

d. Use data to construct and support a reasonable explanation.

e. Communicate scientific procedures and explanations.

B2. Skills and Traits of Technological Design

c. Use appropriate tools, materials, safe techniques, and quantitative measurements to implement a proposed solution to a design problem.

D3. Matter and Energy

c. Describe properties of original materials, and the new material(s) formed, to demonstrate that a change has occurred.

## Grades 6-8

### Science and Technology –

B1.Skills and Traits of Scientific Inquiry

c. Communicate a proposed design using drawings and simple models.

C2. Understandings About Science and Technology

b. Explain how constraints and consequences impact scientific inquiry and technological design.

## 9-Diploma

### Science and Technology –

D1.Universe and Solar System

b. Explain the role of gravity in forming and maintaining planets, stars, and the solar system.

D3. Matter and Energy

d. Describe how light is emitted and absorbed by atoms' changing energy levels, and how the results can be used to identify a substance.

# Performance Indicators Snapshot

The Guide

**Grades 3-5**
Science and Technology
B1.a,b,c,d,e
B2.c
D3.c

**Grades 6-8**
Science and Technology
B1.c
C2.b

**Grades 9-Diploma**
Science and Technology
D1.b
D3.d

# The Electromagnetic Spectrum

For hundreds of years, scientists believed that light energy was made up of tiny particles which they called "corpuscles." In the 1600's, researchers observed that light energy also had many characteristics of waves. Modern scientists know that all energy is both particles, which they now call *photons*, and waves.

Photons travel in *electromagnetic waves*. These waves travel at different *frequencies,* but all travel at the speed of light. The *electromagnetic spectrum* is the range of wave frequencies from low frequencies (below visible light) to high frequencies (above visible light). (See figure below.)

The *radio wave* category includes radio and television waves. These low-frequency waves bounce off many materials.

*Microwaves* pass through some materials but are absorbed by others. In a microwave oven, the energy passes through the glass and is absorbed by the moisture in the food. The food cooks, but the glass container is not affected.

Like other wavelengths, *infrared* or heat waves are more readily absorbed by some materials than by others. Dark materials absorb infrared waves while light materials reflect them. The Sun emits infrared waves, heating the Earth and making plant and animal life possible.

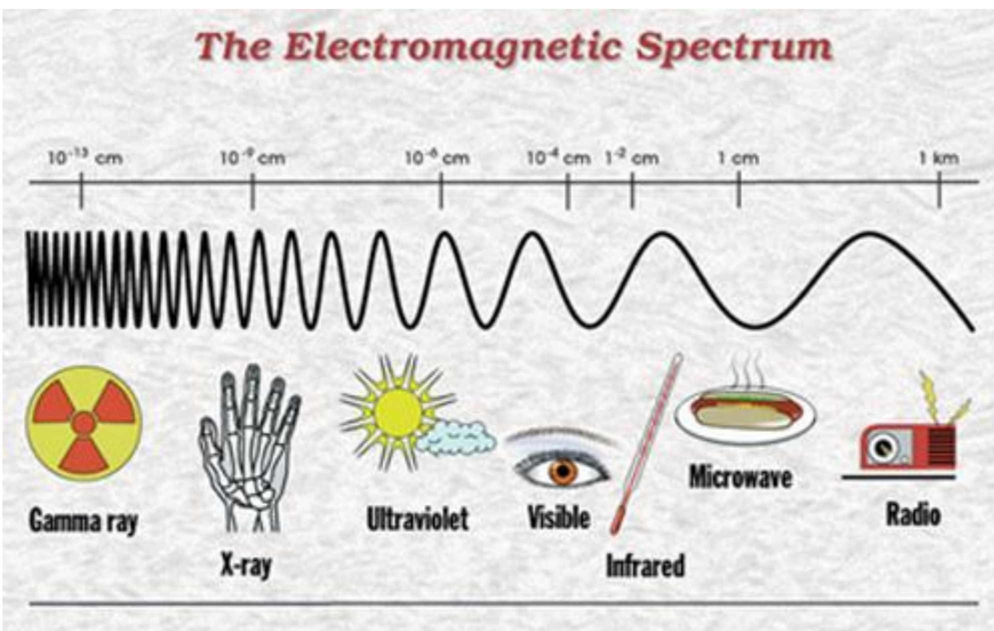
*Visible light* waves are the very smallest part of the spectrum and are the only frequencies visible to the human eye. Colors are different within this category, ranging from the red wavelengths, which are just above the invisible infrared, to violet. Most of the Sun's energy is emitted as visible light.

The Sun also emits many *ultraviolet* waves. High-frequency ultraviolet wavelengths from the Sun cause sunburn.

*X rays* can penetrate muscle and tissue but are blocked by bone, making medical and dental x-ray photographs possible.

*Gamma-ray* waves, the highest frequency waves, are more powerful than x rays and are used to kill cancerous cells.

The atmosphere protects Earth from dangerous ultraviolet, x-ray, and gamma-ray radiation.



# Colors of Stars

Mary Kay Hemenway
The University of Texas at Austin Department of Astronomy
The University of Texas McDonald Observatory
Adapted for UTOPIA by Brad Armosky

Objectives and State of Maine Learning Results Performance Indicators:

1. Learners will be able to analyze the effects of heating and cooling processes in systems. (3-5. Science & Technology. D3.c.)
2. Learners will be able to use appropriate tools, metric units and techniques to gather, analyze, and interpret data. (6-8. Science & Technology. B1.c.)

The General Idea:

Students observe colors in the flame of a burning candle to explore connections between matter, light, color, and temperature — basic concepts of matter and energy. They elaborate on these basic concepts in a new context of astronomy and stars. When matter gets hot enough, it emits visible light. When heated to the same temperature, light bulb filaments, horseshoes, and stars will emit the same characteristic blend of color (or wavelengths) of light. Stars are different colors — white, blue, yellow, orange, and red. The color indicates the star's temperature in its photosphere, the layer where the star emits most of its visible light.

Getting Ready:

- Choose one of the following StarDate radio program scripts for students to read, or you may read it aloud to them: "Spring Triangle" or "Denebola."
  Optional: You may wish to check the StarDate Online web site (http://stardate.org) for interesting radio scripts that will help students find stars of different colors in the night sky. See the "Elaborate" section of this activity.
- Distribute to each group of students: white paper, crayons or colored pencils (lots of different colors), and one candle in a candle holder. Remind students of your classroom's safety rules before beginning.

What You Need:

- StarDate radio script ("Denebola" or "Spring Triangle"); included.
- Candles and candle holders (e.g., cupcakes)
- Matches
- White paper
- Crayons or colored pencils. Offer students a wide variety of colors.
- Construction paper
- Colored chalk
- String
- Spherical balloons (yellow and white)
- Ruler or meter stick

What To Do:

Light the candles. Ask the students to draw what they see in the flame, and to pay special attention to the colors they select. Ask students to record the colors they selected to draw the flame. Some students will use a wide variety of blue, yellow, orange, and red to capture the subtle hues in the flame.

Optional: If you have a digital camera, ask each group to take a picture (flash off) of their candle flame. Use the camera after students have completed their candle flame drawings.

What To Discuss:

When everyone is finished drawing, ask each group to describe what they saw and respond to the following questions:

1. Which part of the flame do you think is the hottest?
   *The blue part is the hottest. Many think that "red" is always the hotter color, so that's what they expect.*
2. As you watch the candle flame, what things or events in everyday life come to mind?
   *Colors of the flame on a gas stove, camp fire, outdoor charcoal grill fire, rocket engine during liftoff, blowtorch, jet engine…*

The answers will usually make the students want to look at their candle flame again, so don't extinguish the flames until all students have reported (unless it becomes a safety issue). Most will notice that the color of the flame is different close to the wick.

*Optional*: Load the digital images onto a computer to display on a video projector. Each group may refer to these images, as well as their drawings, to describe their flame. In stars, just as in Earth-bound fires, blue is hotter than yellow, and yellow is hotter than red. The Sun is much hotter than a candle flame. Unlike a candle, the Sun uses nuclear fusion as its energy source, not a chemical reaction like burning oil or wood. Stars are different colors because they are different temperatures. They are all "hot" compared to most things on Earth; they range in surface temperature from less then 3000 K to over 50,000 K.

Explain to students that when we heat things that don't easily melt (like metal), they first look normal, then begin glowing "red-hot," and later become "white-hot."

Continuations/Extensions:

**Draw scale models of stars**

Because it is difficult to make three-dimensional models that preserve scale, some of the representations of stars in this activity will be flat. On a sidewalk or parking lot, try drawing colored circles in chalk for the larger stars. You can make the smaller ones out of colored construction paper. To begin, students blow up a yellow balloon to represent the Sun, then a white one that is 2.7 times larger (in diameter and circumference) to represent Vega (guide students through solving this problem):

• Measure the circumference of the yellow balloon (Cy) using string.
• Calculate the circumference of the white balloon: Cw = 2.7 ¥ Cy
• Cut a new string to the length of Cw
• Blow up the white balloon until its circumference is Cw.

Students make paper disks the same diameter and color as these two balloons. Now, they compute how large the disk would be for the larger stars. Making a disk to represent a star is like using a flat picture to represent a person. Stars are spheres of hot gas, round like balloons. Students draw the largest diameters outside (using chalk or tracing the outline with string).

To make a circle:

• Measure a piece of string equal to the calculated diameter.
• Fold the string in half and hold at the center
• Place a piece of chalk where the ends of the string meet and trace a circle.

Use the table provided to scale the star diameters. For example, if you begin with a one centimeter Sun, then Betelgeuse will be 8.3 meters! So, this activity takes a lot of space.

| **Star** | **Diameter** (Sun's diameter = 1) | **Color** |
|---|---|---|
| Sun | 1 | Yellow |
| Betelgeuse in Orion | 830 | Red |
| Antares in Scorpius | 775 | Red |
| Vega in Lyra | 2.7 | White |
| Rigel in Orion | 50 | Blue |
| Proxima Centauri C (closest star to the Sun) | 0.03 | Red |
| Dubhe (brightest star in the Big Dipper) | 14 | Orange |

Although stars range in mass from less than one-tenth the mass of the Sun to 100 solar masses, the most massive stars are not the largest. Stars like Betelgeuse and Antares have "puffed up" into red giants hundreds of times the Sun's diameter, yet Betelgeuse is about 20 times more massive than the Sun. There is a lot of empty space inside Betelgeuse. If Betelgeuse is 830 times the Sun's diameter, air at sea level is almost 25,000 times the average density of Betelgeuse.

Evaluate:

**Explore** (20 points)
Candle flame drawing: Students represent the flame with a variety of colors, and accurately proportion parts of the flame. Some may include the wick and candle.

**Explain** (40 points)
1. Which part of the candle flame do you think is the hottest? Why?
   (20 points) Students draw on prior knowledge / everyday experience and their understanding of science concepts in their explanations.
2. As you watch the candle flame, what things or events in everyday life come to mind?
   (20 points) Students list a variety of things and/or events:
   For instance: jet engine, blowtorch, hot oven, bread toaster coils, camp fire, Space Shuttle launch, the Sun, sunset colors…

**Elaborate: Make and draw models of stars** (40 points)
Parts 1 and 2: (10 points) Students inflate the yellow balloon to represent the Sun and inflate the white balloon so that its circumference is 2.4 times larger than the Sun balloon.
Parts 3 and 4: (10 points) Students accurately measure and cut out the paper disks, then correctly calculate the scale diameters for the four large stars in the table.
Part 5: (20 points)
Students accurately calculate the model star radii using the table. The radii depend on the scale size they choose for the Sun.
Students use the string and chalk to draw big circles that represent the large stars:
• Measure a piece of string equal to the calculated diameter.
• Fold the string in half and hold at the center.
• Place a piece of chalk where the ends of the string meet and trace a circle.

Name________________________________________ Date___________________________

# The Color of Stars

Student Worksheet

**Explore**

Draw the candle flame

**Explain**

1. Which part of the flame do you think is the hottest? Why?

2. As you watch the candle flame, what things or events in everyday life come to mind?

**Elaborate:** Make and draw scale models of stars

1. Inflate a yellow balloon to represent the Sun.
2. Inflate a white balloon 2.7 times larger than the Sun balloon. The white balloon represents nearby star called Vega. How do you know if the white balloon is 2.7 times bigger?
3. Make paper disks the same diameter and color as the Sun and Vega balloons.
4. Calculate how large the paper disk would be for the larger stars

| **Star** | **Model diameter** |
|---|---|
| Betelgeuse | |
| Antares | |
| Rigel | |
| Dubhe | |

5. Draw the largest circles outside to represent the four large stars. How do you think you could make the circles using string and chalk?

Scale Size and Colors of Stars

| **Star** | **Diameter** (Sun's diameter = 1) | **Color** |
|---|---|---|
| Sun | 1 | Yellow |
| Betelgeuse in Orion | 830 | Red |
| Antares in Scorpius | 775 | Red |
| Vega in Lyra | 2.7 | White |
| Rigel in Orion | 50 | Blue |
| Proxima Centauri C (closest star to the Sun) | 0.03 | Red |
| Dubhe (brightest star in the Big Dipper) | 14 | Orange |

Use the table to calculate the model star diameters. For example, if you begin with a one centimeter Sun, then Betelgeuse will be 8.3 meters!

**STARDATE CLASSROOM RESOURCES**
StarDate: March 7, 2004

**Denebola**
Leo, the lion, prowls through our evening sky this month, and stands high overhead around midnight. Its two brightest stars mark opposite ends of the constellation. Regulus, the heart of the lion, is at Leo's western edge. And the second-brightest star, Denebola, marks Leo's tail at the constellation's eastern end. Look for it above and to the left of the full Moon this evening, and to the lower left of the brilliant planet Jupiter.

The name Denebola evolved from the ancient Arabic name Al Dhanab al Asad – the lion's tail.

Like the Sun, Denebola is a main-sequence star -- a sedate, comfortable star in the prime of life. But Denebola is a blue-white star, which means that its surface temperature is several thousand degrees hotter than the Sun's. And if you placed the two stars side by side, Denebola would appear about 15 times brighter than the Sun.

This means that Denebola's consuming its nuclear fuel at a faster rate, so it'll live a shorter life.

Denebola is about 40 light-years from Earth. In other words, a beam of light -- speeding along at almost six TRILLION miles every year -- takes 40 years to travel from Denebola to Earth. The light we see from Denebola tonight left the star not long after the first humans were launched into space.

If intelligent beings live on planets in orbit around Denebola, they should just now be receiving the television broadcasts of those early missions.

We'll talk about another prominent star tomorrow.

Script by Damond Benningfield, Copyright 1998, 2001, 2004

**STARDATE CLASSROOM RESOURCES**
StarDate: March 15, 2004

**Spring Triangle**
Summer and winter offer two of the most prominent geometric shapes in the night sky -- the Summer Triangle and the Winter Circle. These patterns of bright stars dominate the evening sky during their respective seasons -- and the Winter Circle is STILL in view in the west as darkness falls.

There's no well-recognized shape for spring, but perhaps there should be. Three bright stars form a tall triangle in the east beginning around 9 p.m. The stars are spread pretty far apart, but they still stand out -- especially from cities, where bright lights overpower most of the fainter stars.
The most prominent member of this triangle is Arcturus, the third-brightest star in the night sky. It's in the constellation Bootes, the herdsman. This brilliant yellow-orange star is low in the east in mid-evening, and wheels high across the sky during the night.

It's a type of star known as a giant, which means it's old and bloated -- a preview of what our own Sun will look like in several billion years.

Well to the right of Arcturus, just a little lower in the sky, you'll see Spica, the brightest star of Virgo. And well above Spica and a little to its right is Regulus, in the constellation Leo. These stars are quite similar. Like the Sun, they're both in the prime of life. But they're hotter than the Sun, so they shine brighter and bluer.

Look for the bright but wide-spread "Spring Triangle" in the east beginning around 9 o'clock.

Script by Damond Benningfield, Copyright 2001, 2004

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# Seeing the Invisible

Objectives and State of Maine Learning Results Performance Indicators:

1. Learners will be able to describe different ways in which light energy travels (9-Diploma. Science and Technology. D3.d)
2. Learners will be able to make observations using appropriate tools and units if measure. (6-8. Science and Technology. B1.c)
3. Learners will be able to compare past and present knowledge about characteristics of stars
(9-Diploma. Science and Technology. D1.b)
4. Learners will be able to describe how scientists gather data about the universe and current explanations for phenomena such as black holes and quasars. (9-Diploma. Science and Technology. D1.)

CB

The General Idea:

Scientists utilize the many forms of non-visible light in order to explore the outer reaches of our galaxy. Million dollar instruments like the Hubble Space telescope and the Chandra X-ray observatory use highly sensitive instruments to capture images of distant stellar phenomenon.

Students will study the invisible light given off by our own sun to better understand the galaxy around them. Most of the electromagnetic spectrum is invisible to our eyes, but these simple experiments created by William Herschel and Johann Ritter elegantly show the existence of longer wavelength infrared radiation and shorter wavelength ultraviolet light.

**Activity 1**: Detecting Infrared Radiation: Herschel's Experiment

What You Need:
- Prism
- light source (the Sun)
- Three thermometers
- Pencil and paper

Getting Ready:

Find a table with easy access to a window or some other source of light. Place the prism on top of a box or stack of books so that the spectrum is projected onto the table.

What To Do:

1. Allow the three thermometers to register the ambient air temperature—about 5 minutes. Take careful note of the temperatures.
2. Create a spectrum on the table using sunlight and the prism.
3. Place thermometers at several points in the spectrum : one in the violet range, one in the center and one just barely beyond the red end. Leave the thermometers in the spectrum for at least five minutes, moving carefully as the sunlight moves the spectrum.
4. Observe the thermometers, changes may be very slight.

What To Discuss:

- Even though one of the thermometers was not in the visible spectrum there was an equal temperature change in all three. Why?
- What are the final readings on each of the three thermometers?

- Why would there be an increase in the temperature beyond the red end of the spectrum?
- What does this tell us about what exists beyond the visible red?

**Activity 2**: Detecting Ultraviolet Radiation: Ritter's experiment

What You Need:

- Several sheets of blueprint paper (available at your local blueprint or architectural firm)
- 1qt. of household ammonia
- flat pan
- prism
- light source (the Sun)
- felt pen

Getting Ready:

Find a table with easy access to a window or some other source of light. Place the prism on top of a box or stack of books so that the spectrum is projected onto the table. Make sure to employ basic safety precautions, as ammonia can be harmful.

What To Do:

Using the prism create a spectrum on the table. Make sure to use light from an open window, as glass blocks most ultraviolet radiation. Take care not to bump the table because this will move the spectrum, altering your results.

1. Working quickly to prevent exposure of the paper to too much light, cut a piece of the blueprint paper about four times larger than the spectrum. Place the blueprint paper into the spectrum. Quickly outline the area covered by the spectrum with a felt-tipped pen. Label the violet end. *Note: Depending on the sensitivity of the paper, different exposure times will be needed. Most exposure times will be fairly brief, however: about 15 to 20 seconds.*
2. Put just enough ammonia in the pan to cover the bottom to a depth of about 0.5 in. (1 cm). In front of an open window or beneath a vent fan, hold the paper over the pan of ammonia so the fumes can process the paper. Notice the changes in the area outlined and the area just beyond the violet end.
   You may notice that this area began to change even before processing with ammonia.

What To Discuss:

- Even though the entire piece of paper was not exposed to the light spectrum you may notice changes over the whole piece of paper. Why?
- What happened to the part of the paper lying where you can see violet?
- What happened to the part of the paper lying just beyond that violet section?
- What does this demonstrate about the area beyond the violet end of the spectrum?

# Simple Spectroscope

www.nasa.gov/pdf/319904maine_The_Electromagnetic_Spectrum.pdf

Objectives and State of Maine Learning Results Performance Indicators:

1. Learners will be able to create a spectroscope using simple equipment, tools, and appropriate metric units of measurement to gather data and extend the senses. (Science & Technology. 3-5. B1.c.)
2. Learners will be able to describe how engineers seek solutions to problems through design and production of products (spectroscopes). (Science & Technology. 6-8. C2.b)

The General Idea:

Simple spectroscopes, like the one described here, are easy to make and offer users a quick look at the color components of visible light. Different light sources (incandescent, fluorescent, etc.) may look the same to the naked eye but will appear differently in the spectroscope. The colors are arranged in the same order but some may be missing and their intensity will vary. The appearance of the spectrum displayed is distinctive and can tell the observer what the light source is.

Management and Tips:

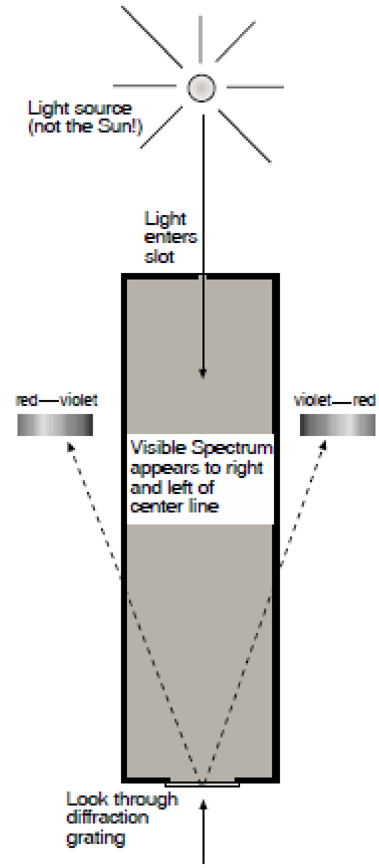
The analytical spectroscope activity that follows adds a measurement scale to the spectroscope design. The scale enables the user to actually measure the colors displayed. As will be described in greater detail in that activity, the specific location of the colors are like fingerprints when it comes to identifying the composition of the light source. Refer to the background and management tips section for the Analytical Spectroscope activity for information on how diffraction gratings produce spectra.

Spectroscopes can be made with glass prisms but prisms are heavy. Diffraction grating spectroscopes can do the same job but are much lighter. A diffraction grating can spread out the spectrum more than a prism can. This ability is called dispersion. Because gratings are smaller and lighter, they are well suited for spacecraft where size and weight are important considerations. Most research telescopes have some kind of grating spectrograph attached. Spectrographs are spectroscopes that provide a record, photographic or digital, of the spectrum observed. Many school science supply houses sell diffraction grating material in sheets or rolls.

One sheet is usually enough for every student in a class to have a piece of grating to build his or her own spectroscope. Holographic diffraction gratings work best for this activity. Refer to the note on the source for holographic grating in the next activity. A variety of light sources can be used for this activity, including fluorescent and incandescent lights and spectra tubes with power supplies. Spectra tubes and the power supplies are available from school science supply catalogs. It may be possible to borrow tubes and supplies from another school if your school does not have them. The advantage of spectrum tubes is that they National Aeronautics and Space Administration 28 provide spectra from different gases such as hydrogen and helium. When using the spectroscope to observe sunlight, students should look at reflected sunlight such as light bouncing off clouds or light colored concrete. Other light sources include streetlights (mercury, low-pressure sodium, and high-pressure sodium), neon signs, and candle flames.

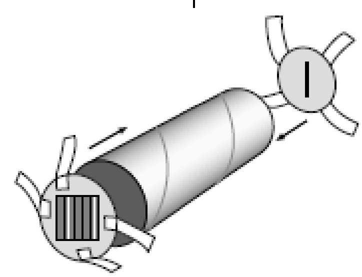
What You Need:

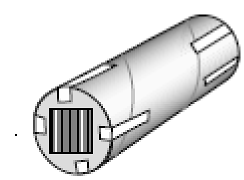
- Diffraction grating, 2-cm square (See management
- and tips section.)
- Paper tube (tube from toilet paper roll)
- Poster board square (5 by 10-cm)
- Masking tape
- Scissors
- Razor blade knife
- 2 single-edge razor blades
- Spectrum tubes and power supply (See
- management and tips section.)
- Pencil




What To Do:

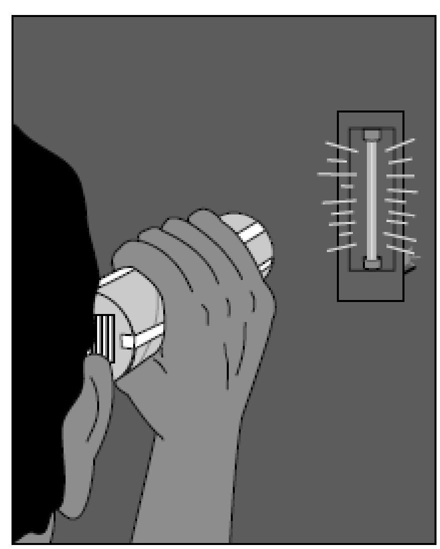
1. Using the pencil, trace around the end of the paper tube on the poster board. Make two circles and cut them out. The circles should be just larger than the tube's opening.
2. Cut a 2-centimeter square hole in the center of one circle. Tape the diffraction grating square over the hole. If students are making their own spectroscopes, it may be better if an adult cuts the squares and the slot in step 4 below.
3. Tape the circle with the grating inward to one end of the tube.
4. Make a slot cutter tool by taping two single- edge razor blades together with a piece of poster board between. Use the tool to make parallel cuts about 2 centimeters long across the middle of the second circle.
5. Use the razor blade knife to cut across the ends of the cuts to form a narrow slot across the middle of the circle.
6. Place the circle with the slot against the other end of the tube. While holding it in place, observe a light source such as a fluorescent tube. Be sure to look through the grating end of the spectroscope. The spectrum will appear off to the side from the slot. Rotate the circle with the slot until the spectrum is as wide as possible. Tape the circle to the end of the tube in this position. The spectroscope is complete.
7. Examine various light sources with the spectroscope. If possible, examine nighttime street lighting. Use particular caution when examining sunlight. Do not look directly into the Sun.





What To Discuss:

- How do astronomers measure the spectra of objects in space? What do those spectra tell us about these objects?
- Investigate other applications for the electromagnetic spectrum.

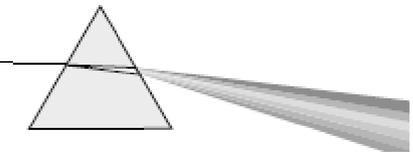


Assessment:

Compare student drawn spectra from different light sources.

# Student Sheet - Simple Spectroscope

Name________________________________________



Use your spectroscope to analyze the colors of light given off by different sources. Reproduce the spectra you observe with crayons or colored markers in the spaces below. Identify the light sources. (**When using the Sun as a light source, do not look at it directly with your spectroscope. You can harm your eye. Instead, look at sunlight reflected from a white cloud or a sheet of white paper.**)

Light Source: ______________________

Light Source: ______________________

Light Source: ______________________

1. Describe how the spectra of the three light sources you studied differed from each other. How were they similar?

2. Would you be able to identify the light sources if you only saw their visible spectra?

**The Maynard F. Jordan Planetarium - Cosmic Classroom Activity**

# Discovering Color With a Prism

from Optics: An Educators Guide with Activities in Science and Mathematics
http://www.nasa.gov/pdf/58258main_Optics.Guide.pdf

Objectives and State of Maine Learning Results Performance Indicators:

1. Learners will be able to use simple equipment and tools to gather data and extend the senses. (Science & Technology. 3-5. B1.c)
2. Learners will be able to pose investigable questions and seek answers from reliable resources of scientific information and from their own investigations. (Science & Technology. 3-5. B1.a.)
3. Learners will be able to use appropriate tools, materials, safe techniques, and quantitative measurements to implement a proposed solution to a design problem. (Science & Technology. 3-5. B2.c.)

The General Idea:

The student will observe what happens to light as it passes through a prism. The student will experiment with white light that is composed of a continuous band of colors. The band of colors appears in the same pattern as the colors of a rainbow.

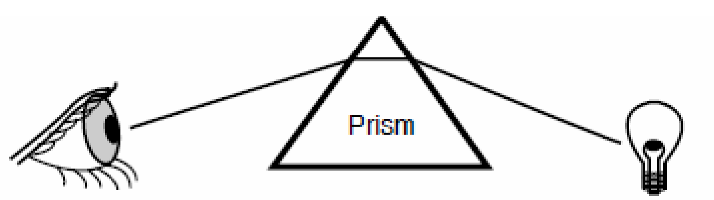
This experiment was first done by Sir Isaac Newton (1642–1727). Newton let a beam of sunlight pass through a glass prism and observed the white light spectrum. In a vacuum, light of all colors travels at the same speed. When light passes through a material, such as glass or water, the red light at one end of the spectrum travels faster than the violet light at the other end of the spectrum. This difference in speed causes a change in the direction of light when going from air to glass and from glass to air. This change of direction is called refraction, and is greater for violet light than for red light. The speed of light in the glass depends on the color; thus we get a continuous band as in the rainbow

What You Need:

- glass or plastic prism
- light sources, including an incandescent lamp, fluorescent lamp, cadmium lamp
- a prism made out of acrylic plastic (optional)

What To Do:

1. Hold the small prism with one finger at the top and one finger at the bottom. Position the prism 2 to 3 inches in front of your eye. Look through one side of it in the direction of the light source as shown below.




2. First, look at the incandescent lamp. Observe the colors that are visible as you view this lamp.
3. Next, view the fluorescent lamp and then the cadmium lamp. (The kinds of light source may vary.)
4. Record your observations in the next section.

Assess & Discuss:

1. Observe the colors from the three different light sources and list them in order in the chart below.
2. Start with the first color on the left and list them as you see them.
   (Hint: ROY G. BIV—red, orange, yellow, green, blue, indigo, violet)

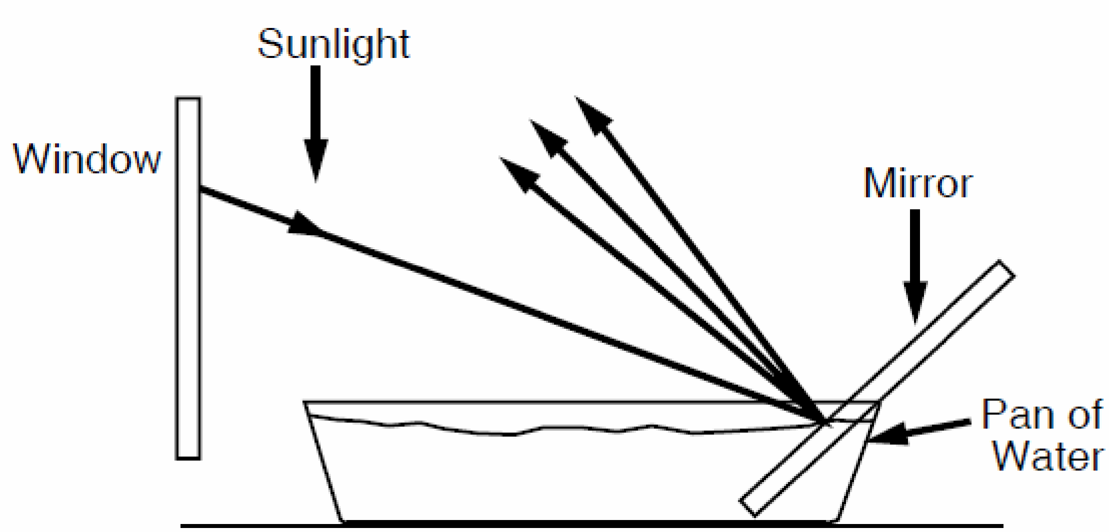
| Light Source | Colors |
|---|---|
| Incandescent Lamp | |
| Fluorescent Lamp | |
| Cadmium Lamp | |

3. What differences and/or similarities did you observe in each light source when looking through the glass, plastic or acrylic plastic?
4. Were the colors always in the same order?
5. Were the colors always in bands?
6. Did the bands always form the same shapes?
   *Hint:* An artificial light source will not transmit the complete spectrum unless it is a white light source.

Extensions:

Repeat the previous activities with a high quality prism (highly dispersive). What differences do you observe between the acrylic plastic or plastic prism and the prism made out of optical quality glass?

You can make a prism at home by placing a flat mirror in a shallow pan of water. Put the pan of water in a window where the Sun can shine into the water. (See the figure below.) The sunlight reflected from the mirror can be seen as a rainbow of colors reflected on a wall.



Answers to Discussion Questions:

1. By refraction, a prism can break white light up into its seven major colors. Some of the suggested light sources will appear to be white light to the eye, but a prism will show that some wavelengths are not present.
2. The acrylic plastic or plastic prism will refract and break the light into color, but the quality of the plastic or glass will determine the sharpness of the colors.
3. Colors always come out of a prism in the same order. Some colors will be omitted if the light source is not white light.
4. The colors blend or shade into each other.
5. The bands of color do not always have the same shape or width. The shape or width of the color band depends on the type of light source.

# Light and Color

from Optics: An Educators Guide with Activities in Science and Mathematics
http://www.nasa.gov/pdf/58258main_Optics.Guide.pdf
Level – K-4, 5-8

Objectives and State of Maine Learning Results Performance Indicators:

1. Learners will be able to plan and safely conduct investigations including simple experiments that involve a fair test. (Science & Technology. 3-5. B1.b)
2. Learners will be able to use simple equipment, tools, and appropriate metric units of measurement to gather data and extend the senses. (Science & Technology. 3-5. B1.c)
3. Learners will be able to use data to construct and support a reasonable explanation. (Science & Technology. 3-5. B1.d)
4. Learners will be able to communicate scientific procedures and explanations. (Science & Technology. 3-5. B1.e)

## Part I – Color Spinners

The General Idea:

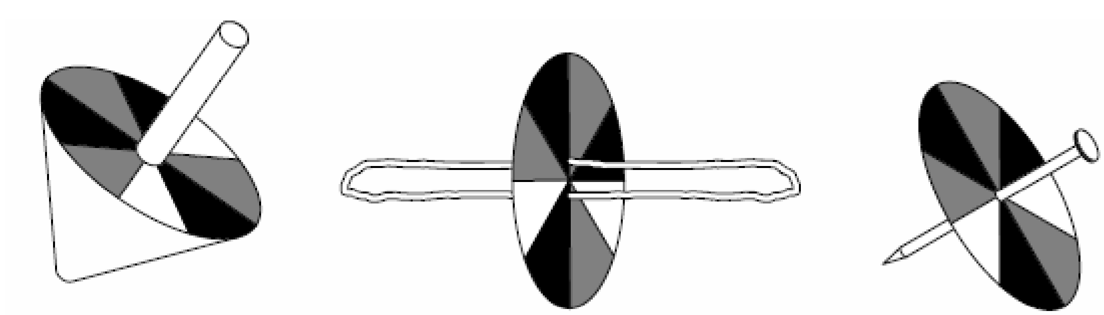
The student will observe the effects of rapid movement using colors. The student will observe how colors change and how different colors can be made. Some colors are made by adding or subtracting parts of the colors in the spectrum. When designs of more than one color are moved rapidly, the human eye sees these colors blended or mixed.

What You Need:

- strong string such as kite string
- white cardboard circles 2 to 4 inches in diameter
- magic markers or washable paint
- scissors

What To Do:

1. Color the circles with the magic markers. You may color each section a different color or draw a colorful design.
2. When you have colored the circle on both sides, punch two holes in the center of the circle about one-half to one-quarter inch apart.
3. Cut a piece of string about 36 to 48 inches long. Thread the string through the two holes and tie the two ends together.
4. Now hold a piece of the string in each hand and twist it. Pull the string and make the paper circle spin.



Observations, Data, and Conclusions:

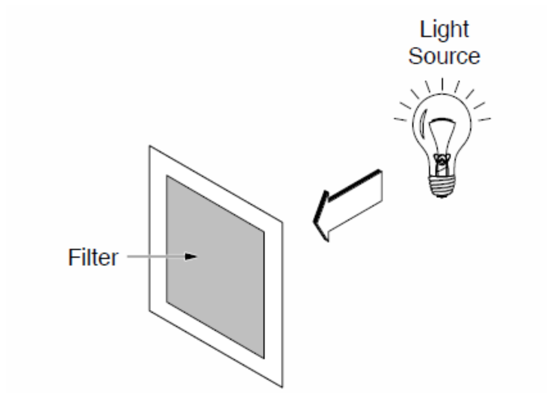
1. Observe the pattern on the spinning circle. What did you see?
2. What colors did you see?
3. Did the colors seem to mix and become other colors?
4. How can you make green?
5. How can you make orange?
6. How can you make gray or white?
7. How can you make brown?
8. Can you make stripes? How?
9. What else can you make? Keep experimenting!

**Part II – Filters (K-4)**

The General Idea: The student will experiment with color by using a variety of filters. Light is the only source of color. Color pigments (paints, dyes, or inks) show color by absorbing or subtracting certain parts of the spectrum, and reflecting or transmitting the parts that remain. The visual sensation of all the colors can be created by adding different intensities or amounts of the three primary colors—red, green, and blue. Filters subtract or absorb a band of wavelengths of color and transmit the other wavelengths. A yellow filter transmits yellow and a red filter transmits red.

What You Need:

- a variety of transparent filters or cellophane of different colors
- light source such as a window
- slide projector or overhead projector




What To Do:
Place a filter in front of the light source. Combine two colored filters. Now combine three colors. Experiment with many different combinations.

Observations, Data, and Conclusions:
1. What colors can you make with two different filters?
2. What colors can you make with three different filters?
3. How many different colors can you make?
4. What did you learn about color filters?

**Part III – Hidden Messages**

The General Idea: The student will construct, experiment, and observe with designs viewed through color filters. A totally transparent piece of glass transmits all wavelengths of light. An opaque object will transmit no light at all. A red filter transmits red, a blue filter transmits blue, and a yellow filter transmits yellow; so that all other colors are absorbed or subtracted. Some manmade sources of light, such as fluorescent bulbs, cause objects to appear to be different colors because they do not generate all the wavelengths of white light.

What You Need:

- white paper
- highlight or pastel magic markers (three or more colors)
- transparent color filter or cellophane in a variety of colors
- a card with several hidden messages of different colors (handmade)

What To Do:

1. Using at least 3 different magic marker colors, draw a design. Think in terms of space and astronomy designs.
2. Use magic markers to draw more designs, be sure to include at least one hidden message in your designs. Can you hide three or more messages in one design? (Students should use a space or astronomy word as their hidden message and then draw designs over it.)
3. View the design through several filters.

Observations, Data, and Conclusions:

1. When you viewed the designs without a filter, what did you see?
2. What did you see when you looked at your design with each colored filter?
3. What did you see when you used two different filters together?
4. Why did you see different things with each different filter?
5. If possible, exchange designs with another person and read their secret message.

# Vocabulary List

| | |
|---|---|
| Absorption lines | Dark lines that are produced in a spectrum because intervening atoms absorbed photons of specific wavelengths. |
| Angstrom | An angstrom is 1/1000,000,000 of a centimeter |
| Dispersion | The separation of white or compound light into its respective colors, as in the formation of a spectrum by a prism. |
| Doppler effect | The shift in frequency (Doppler shift) of acoustic or electromagnetic radiation emitted by a source moving relative to an observer as perceived by the observer: the shift is to higher frequencies when the source approaches and to lower frequencies when it recedes. |
| Electromagnetic Spectrum | The full range of electromagnetic radiation spread out by wavelength, it consists of gamma-rays, X-rays, ultraviolet rays, optical light, infrared radiation, microwaves, and radio waves. Wavelength, energy, frequency, or temperature can classify these electromagnetic waves. |
| Filter length | The distance between the principal focus of a lens or mirror and its optical center. |
| Frequency | The number of waves that pass a point in a given unit of time. |
| Gamma ray | High energy wave of high frequency and with a wavelength shorter than an x-ray; released in a nuclear reaction. |
| Infrared radiation | Invisible radiation with a longer wavelength than red light and next to red light in the electromagnetic spectrum; used in heat lamps, to detect heat loss from buildings, and to detect certain tumors. |
| Lens | A curved, transparent object; usually made of glass or clear plastic and used to direct light. |
| Light | A form of energy, traveling through the universe in waves. The wavelengths of visible light range from less than 4,000 angstroms to more than 7,000 angstroms. |
| Luminosity | The rate of radiation of electromagnetic energy into space by a star or other object. |
| Magnitude | The units used to describe brightness of astronomical objects. The smaller the numerical value, the brighter the object. |
| Optics | The branch of physical science that deals with the properties and phenomena of both visible and invisible light, and with vision. |
| Prism | A transparent solid object, often having triangular bases, used for dispersing light into a spectrum or for reflecting rays of light. |
| Redshift | An increase in the wavelength of radiation emitted by a celestial body as a consequence of the Doppler effect. |
| Spectroscope | An optical device for producing and observing a spectrum of light or radiation from any source, consisting essentially of a slit through which the radiation passes, a collimating lens, and an Amici prism. |
| Visible light spectrum | Band of visible colors produced by a prism when white light is passed through. |
| Wavelength | The total linear length of one wave crest and trough. |
| x-ray | Invisible electromagnetic radiation of great penetrating power. |

## Some good books to use with *Cosmic Colors*

**The Secret Language of Color**

Eckstut, Joann, Arielle Eckstut. 2013, Black Dog and Leventhal Publishers, Inc.

*Why is the sky blue, the grass green, a rose red? Most of us have no idea how to answer these questions, nor are we aware that color pervades nearly all aspects of life, from the subatomic realm and the natural world to human culture and psychology.*

**ROY G. BIV: An Exceedingly Surprising Book About Color**

Stewart, Jude. 2013, Bloomsbury USA.

*Color is all around us every day. We use it to interpret the world—red means stop, blue means water, orange means construction. But it is also written into our metaphors, of speech and thought alike: yellow means cowardice; green means envy—unless you're in Germany, where yellow means envy, and you can be "beat up green and yellow."*

**COLORS: An eBook for Teens and Young Adults about Colors and Light**

Hoffman, Karl. 2014, Amazon Digital Services, Inc.

*A popular book, filled with over 40 pictures, that provides children and teenagers the basic knowledge about colors. Includes information such as what color light is, what does a wavelength have to do with color, and the visual spectrum and color theory.*

**Astronomical Spectroscopy for Amateurs (The Patrick Moore Practical Astronomy Series)**

Harrison, Ken. Springer; 2011 edition.

**Seeing the Sky: 100 Projects, Activities & Explorations in Astronomy**

Schaaf, Fred. 2012 (Reprint), Dover Publications.

*Geared toward beginning astronomers, this entertaining guide was written in direct, nontechnical terms by an experienced astronomer and well-known author. Daylight and nighttime activities include sightings of comets, meteors, stars, and planets as well as phases of the moon, halos, twilights, and many other intriguing phenomena.*

## Some good web sites to use with *Cosmic Colors*

**sunearthday.gsfc.nasa.gov/2006/educators/index.php**

Designed to provide essential materials needed to help your students see our sun in a different light.

**www.nasa.gov/pdf/58258main_Optics.Guide.pdf**

Optics: Light, Color, and Their Uses. An Educator's Guide with activities in Science and Mathematics.

**solar-center.stanford.edu/activities/cots.html**

Additional activities using spectroscopes.

## Lessons From The World Wide Web

Also, a wide variety of lesson plans and activities can be found on the World Wide Web. These sites are dedicated to lesson planning in a variety of subjects.

**btc.montana.edu/ceres**
*Maintained by the Burns Telecommunications Center, this page links to educational activities and classroom resources*

**spaceplace.jpl.nasa.gov/spacepl.htm**
*This California Institute of Technology and NASA Jet Propulsion Laboratory site for kids offers information and activities*

**school.discoveryeducation.com/**
*This Discovery Channel education site allows teachers to search for lesson plans by grade and subjects*

**www.eduref.org/cgi-bin/lessons.cgi/Science/Astronomy**
*Lesson plans based of the popular PBS series, Newton's Apple*

**www.thegateway.org**
*Sponsored by The U.S. Department of Education's National Library of Education and ERIC Clearinghouse on Information & Technology, this site offers lesson plans for all subjects and all grades*

## Astronomy Web Sites Worth a Visit

**Galaxymaine.com**
*The Maynard F. Jordan Planetarium and Observatory home page*

**Galaxymaine.com/SA/SA2.htm**
*The teacher resources and bibliography page on the Maynard F. Jordan Planetarium web site*

**space.jpl.nasa.gov**
*NASA's Jet Propulsion Laboratory web site*

**ssd.jpl.nasa.gov**
*A site about our solar system maintained by the Solar System Dynamics Group of the Jet Propulsion Laboratory*

**hawastsoc.org**
*The Hawaiian Astronomical Society's home page*

**www.nss.org**
*The National Space Society web site*

**stardate.org**
*Learn what's going on TODAY in astronomy on the "Star Date" web page, maintained by the University of Texas' McDonald Observatory*

*The Maynard F. Jordan Planetarium does not guarantee that the information given on the above web sites to be accurate, accessible, or appropriate for students.*